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ABSTRACT

A study investigated changes in prospective elementary teachers' conceptions about projectile motion. The preservice teachers (enrolled in reading methods courses) were either told or not told that they were expected to teach a videotaped lesson on projectile motion. In addition, they either participated in a combined demonstration-reading or in a reading-only group. Seventy-three prospective teachers with non-scientific conceptions were randomly assigned to one of four groups comprised of the two levels of the two conditions (Told/Not Told, Demo/No Demo) and had their conceptual change documented through short-answer, true-false, and application tasks. Additional data were obtained from a questionnaire to determine the influence of prospective teachers' attitudes and experiences on conceptual change. Further, the videos and transcriptions of 16 videotaped lessons and post-lesson structured interviews were analyzed to provide information about the interaction of variables producing change and to track the changes in thinking that were made. Results indicated the effectiveness of a combined demonstration-reading condition and the effectiveness of text in producing long-term change. Qualitative analyses indicated an interaction among instructional, motivational, and knowledge factors, documented that restructuring of knowledge may lead to new non-scientific conceptions, and suggests that conceptual change is dynamic and proceeds in a piecemeal fashion. (Seven tables of data are included; 32 references and examples of matrices are attached.) (Author/RS)

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Prospective Teachers' Comprehension and Teaching of a Complex Science Concept

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READING RESEARCH REPORT NO. 4
Fall 1993

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National Reading Research Center

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About the National Reading Research Center

The National Reading Research Center (NRRC) is funded by the Office of Educational Research and Improvement of the U.S. Department of Education to conduct research on reading and reading instruction. The NRRC is operated by a consortium of the University of Georgia and the University of Maryland College Park in collaboration with researchers at several institutions nationwide.

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Abstract. This study investigated changes in prospective teachers' conceptions about projectile motion. The preservice teachers participating in the study were either told or not told that they were expected to teach a videotaped lesson on projectile motion. In addition, they either participated in a combined demonstration-reading or in a reading-only group. We randomly assigned 73 prospective teachers with non-scientific conceptions to one of four groups comprised of the two levels of the two conditions (Told/Not Told, Demo/No Demo) and documented conceptual change through short-answer, true-false, and application tasks. Additional data were obtained from a questionnaire to determine the influence of prospective teachers' attitudes and experiences on conceptual change. Further, the videos and transcriptions of 16 videotaped lessons and post-lesson structured interviews were analyzed to provide information about the interaction of variables producing change and to track the changes in thinking that were made. The results indicated the effectiveness of a combined demonstration-reading condition and the effectiveness of text in producing long-term change. Qualitative analyses indicated an interaction among instructional, motivational, and knowledge factors, documented that restructuring of knowledge may lead to new non-scientific conceptions, and led us to hypothesize that conceptual change is dynamic and proceeds in a piecemeal fashion.

Elementary school teachers often feel unprepared to teach students science, yet are required to do so. Not only is science a required part of the curriculum, it is also important. Some of the more complicated problems facing Earth (e.g., global warming) can only be solved with the aid of scientific knowledge; therefore it is vital that students have firm backgrounds in and positive attitudes toward science. Unfortunately, many teachers have themselves experienced poor science instruction or may lack scientific knowledge for other reasons. They have poor attitudes about science, and they hold non-scientific notions that they are in danger of passing on to others

(Pratt, 1981; Lederman & Gess-Newsome, 1991).

An understanding of how prospective teachers change their non-scientific ideas to scientific ones is important. If researchers can understand what causes teachers to change their ideas, they may be able to help teachers understand the process of change, thus enabling them to help their students adopt scientific principles. In this study, we investigated the role of instruction (demonstration and text designed to foster cognitive conflict) in helping prospective elementary teachers replace their non-scientific notions about motion with scientific ones. We wished to teach the scientific concept that a horizontally propelled or carried object, if released, will assume the path of a parabolic arc on its way to the ground because the object will maintain its forward motion at the same time it is pulled downward by gravity. We believed that conceptual change is necessary for learning this concept, because previous studies have shown it to be highly counterintuitive (e.g., McCloskey, 1983). We also studied the interaction of affective factors and instruction to develop hypotheses about the conditions necessary for conceptual change. In the next section, we review research that influenced our study.

Prior Knowledge and Conceptual Change

While prior knowledge can enhance the ability to learn new concepts, it can also inhibit learning when those new concepts contradict it. Researchers (e.g., McCloskey, 1983; Maria & MacGinitie, 1981; Marshall, 1989) have found that students whose ideas conflict with new information often disregard the new information. Theorists hypothesize that peoples' tendency to favor prior knowledge over new information is the result of their having ingrained beliefs and intuitions originating in individual experiences and social, motivational, and cultural influences (Schommer, 1990; Strike & Posner, 1992). In order for new learning to take place, instruction must overpower resistance from these factors.

In this paper, we make a distinction between "learning" and "conceptual change." Learning may involve but is not limited to conceptual change; conceptual change is one kind of learning. Although learning often involves the mere addition of new information into a person's schemata, conceptual change involves some reorganization of existing schemata. Hewson and Hewson (1984) and later White and Gunstone (1989) call this process of reorganization *conceptual exchange* and contrast it with rejection, memorization, and reconciliation (or *conceptual capture*) of new concepts. Rejection and memorization place no demands on existing beliefs. When existing beliefs coincide with a new concept, a student must simply "capture" or add the new concept. It is only through conceptual exchange that existing beliefs are altered.

Posner, Strike, Hewson, and Gertzog (1982) hypothesize that there are four essential conditions for conceptual change. These include (a) dissatisfaction with one's current conception as a result of instruction (e.g., demonstration), followed by the degree to which the new conception is deemed (b) intelligible, (c) plausible, and (d) useful. Conflict or dissonance between one's non-scientific ideas

and newly encountered scientific concepts is a major component of this scheme, but other theorists emphasize other components such as a "bridge" between known and unknown ideas (Brown & Clement, 1987) and integration of separate experiences (Karmiloff-Smith, 1984). In this study, we tried to foster cognitive dissonance in several ways, and we looked for evidence that our participants experienced it.

Attitudes, Motivation, and Conceptual Change

Conceptual change often seems related to positive attitudes and the motivation to learn. Personal motives and goals for learning were not considered in Posner, Strike, Hewson, and Gertzog's (1982) initial formulation of their theory, but in a revision of that theory, Strike and Posner (1992) stated: "A wider range of factors needs to be taken into account in attempting to describe a learner's conceptual ecology. Motives and goals and the institutional and social sources of them need to be considered" (p. 10). It seems reasonable that negative attitudes and lack of motivation can impinge on a person's desire to put effort into learning. When attitudes and motivation are poor, the tendency to hold onto existing concepts may be strengthened. Although the effects of attitude and motivation on conceptual change are not well understood, their negative effects on *learning* have been reported by Gillingham, Garner, Guthrie, and Sawyer (1989) and Gay (1986), who noted that poorly motivated learners chose not to utilize abundant and helpful resources to access relevant information in understanding a topic. Research that investigates the relations between attitude and achievement in science, however, suggests only small to moderate relations between the two (Talton & Simpson, 1987; Schibeci, 1989). The effect of attitudes in promoting conceptual change remains to be seen.

Researchers often allude to the low motivation of elementary school teachers for teaching physics, the topic of our study. Shymansky, Yore, and Good (1991) point to teachers' concerns for covering content and their sense of having too little time in which to accomplish their goals as being sources of discouragement and lowered motivation. Pratt (1981) and Lederman and Gess-Newsome (1991) note teachers' lack of comfort in teaching science. This lack of comfort results from feelings of unpreparedness and the idea that some topics in science are not well understood. According to Lederman and Gess-Newsome (1991), new teachers most often feel unprepared, and, in fact, do not have a unified scheme of the scientific knowledge they are required to teach.

Elementary school teachers, too, may simply dislike physics or other science topics and may regard physics as irrelevant. Indeed, the idea that physics is intelligible, plausible, and useful (three of the four conditions thought necessary for conceptual change) may be foreign to both teachers and students. Possibly for these reasons, the textbook becomes the driving force behind the curriculum (Harms, 1981; Stake & Easley, 1978). While the attitudinal and motivational factors discussed here surely affect learning and the subsequent effectiveness of the teaching of counter-intuitive physics principles, the relation between these factors has not been clarified by research.

In our study, we attempted to investigate the conditions necessary for prospective elementary school teachers to adopt counterintuitive scientific principles. Our specific purposes were (a) to test the effect of instruction (a combination of demonstration and text) aimed at overcoming prior knowledge that conflicts with scientific thinking, (b) to enhance motivation to learn by making the target concept appear useful, (c) to investigate the interaction of attitudinal and experiential variables and their effects on conceptual change, and (d) to observe the changes that targeted students made in their thinking as they proceeded through the phases of this study. We asked five questions:

(1) Will combining demonstration and reading enable prospective teachers to overcome their prior conceptions?

(2) Will telling prospective teachers that they will be expected to teach a concept provide the necessary motivation for overcoming prior conceptions?

(3) What influences do prior experiences and attitudes have on conceptual change?

(4) What changes in thinking do prospective teachers make as they proceed from being taught a physics principle to actually teaching the principle themselves?

(5) What interactions among variables help explain why some teachers learn counterintuitive information and others do not?

While the first two questions were investigated experimentally, the others were not; our observations led us, instead, to hypothesis generation.

METHOD

Participants

The participants were drawn from a pool of 94 elementary education majors enrolled in the first of two reading methods courses at a large state-supported university in the southeastern United States. Approximately 95% of the subject pool consisted of white, middle-class females between the ages of 19 and 25 who lived in small towns and cities within the state served by the university. Each participant had been admitted to the teacher education program on the basis of having earned a minimum 2.5 grade point average. Participants reported taking as few as 2 and as many as 7 science courses throughout high school and college. Approximately 72% reported having taken a physical science course, and they had taken a science methods course as part of their teacher education program.

Of the 94 participants, 4 were dropped at the beginning of the study when a pretest revealed that they had scientifically accepted conceptions about projectile motion. Of the 90 prospective teachers having non-scientific conceptions, 17 chose not to be part of the study. Therefore, 73 prospective teachers, actually participated.

The Concept

We taught the idea that a propelled object or a carried object that is released will maintain its forward motion at the same time that it is

pulled by gravity, so that the path of the object to the ground will be a parabolic arc. We knew from previous studies that the physics principle we proposed to teach was counterintuitive because it appeared to contradict everyday experiences in the real world (e.g., McCloskey, 1983). The principle is derived from Newton's theory of motion and contradicts the pre-Newtonian belief that an object set in motion eventually stops or changes direction from loss of an *internal force*. Our previous work with high school and college students on this topic revealed that more than 90% lacked the understanding that gravity and the force that places an object in forward motion are external and act simultaneously to cause the projectile to form an arced path on its way to the ground (Alvermann & Hynd, 1989; Hynd & Alvermann, 1989).

The Conditions

We decided to teach this Newtonian principle of forward motion while manipulating two variables thought to be important factors in conceptual change: (a) dissatisfaction with one's current conception as a result of instruction as brought about by a combination of prediction, demonstration of a counterintuitive process, and reading, and (b) the degree to which a newly formed conception is deemed useful.

Prediction/Demonstration. Our prediction/demonstration technique was consistent with science educators' notions that there must be some cognitive conflict before non-scientific conceptions can be changed. Borrowing an idea from Romey (1968), we demonstrated the principle of forward motion in a way intended to cause cognitive conflict. To confront prospective teachers' beliefs about motion, we asked them to predict where an object carried at shoulder-height would fall if dropped. Based on results from the pretest they had taken and previous research findings (e.g., McCloskey, 1983), we were confident that most prospective teachers would predict that the object would fall *straight down* or *backwards*. Then, we had them observe while we dropped the object. Using a piece of tape on the floor as a point of reference, we demonstrated that a carried object falls *in front of* the release point. After our demonstration, we asked the teachers if their predictions were correct and, if not, to explain what really happened, encouraging them to describe the simultaneous interaction of vertical and horizontal forces. We also asked them to predict the path that cargo dropped from a moving airplane would take; then we showed a film that depicted the cargo falling forward in a curved path. Finally, we had participants make predictions about the path of a penny being shoved off a table and a bullet being fired from a gun. After each demonstration, we had them explain why the demonstration proceeded as it did, helping them to emphasize the effects of forward motion and gravity. We also offered participants an opportunity to try the demonstrations themselves, where appropriate.

Although the demonstration procedure took only a small amount of time (approximately 15-20 minutes), we felt it involved the teachers in some relatively complex processing of the targeted principle on several levels. It also involved them in using the predic-

tion/demonstration procedure often recommended by science educators (Anderson & Smith, 1987; Champagne, Gunstone, & Klopfer, 1983; Shymansky, et al., 1991). Indeed, researchers have documented the effectiveness of demonstration at producing conceptual change when combined with other instruction, most notably text. Marshall (1989) and Swafford (1989) found that combining demonstration and text produced greater conceptual change than demonstration or text only. Guzzetti, Snyder, Glass and Gamas's (1993) meta-analysis revealed that approaches including demonstration appeared to be helpful, possibly because they produced dissatisfaction with previous predictions, thus meeting Posner, Strike, Hewson, and Gertzog's (1982) first condition for conceptual change.

Usefulness. The other variable, usefulness, was chosen in deference to Posner, Strike, Hewson, and Gertzog's (1982) notion that for conceptual change to occur, the new concept must appear useful. Half of the prospective teachers read a statement indicating that they should pay close attention to the information to be learned because they would be teaching it to an elementary school student. The other half did not read that statement. We were hoping to convince the prospective teachers who read the statement that it would be useful for them to learn the concept, thereby increasing their motivation.

Instrumentation

Stimulus text. A 606-word expository passage that had been adapted from an article written for *Scientific American* (McCloskey, 1982) and titled "Newton's Theory of Motion" was given to all study participants. The adaptation was checked for accuracy by a research professor of physics at the university where the study was conducted. The text was designed to stimulate cognitive conflict and to make the scientific concept understandable and plausible while showing its usefulness. Calculated to be at the tenth grade readability level according to the Fry Readability Formula (Fry, 1977), the passage refuted commonly held conceptions about motion. Specifically, it refuted impetus theory, the naive pre-Newtonian explanation of projectile motion, which asserts that objects have internal forces that dissipate over time. Several examples in the text illustrated how Newtonian theory explains the motion of objects. The theory's usefulness was demonstrated by its power to explain the path of a carried object that was dropped while in motion and the path of a bullet fired from a gun. Such refutational texts have previously been found to bring about conceptual change even if not combined with other instruction. Guzzetti, Snyder, Glass and Gamas (1993), for example, discovered that all forms of refutational text, when considered together, were superior to all kinds of non-refutational text across grade levels.

Test materials. Two of the four pretests designed to measure participants' prior knowledge about projectile motion were adapted from materials validated by Valencia, Stallman, Commeyras, & Greer (1987). The first pretest, the test of appropriateness, assessed participants' ability to differentiate among phrases that *would*, *might*, or *would not* be likely to appear in science textbook chapters

about motion. *An object accelerates, a curved path,* and *chemical changes that occur* were three of the ten phrases on the test of appropriateness. The second pretest was called the test of relatedness (also adapted from Valencia, Stallman, Commeyras, & Greer, 1987). It assessed participants' ability to distinguish whether vocabulary terms were related or not related to the concept of motion. *Gravity, growth,* and *velocity* were three of the ten terms on the test of relatedness. The third pretest was a shortened version (n=10 items) of an experimenter-constructed 21-item true-false test (test/retest reliability coefficient= .71). On this test, a true item reflected Newton's theory; a false item reflected impetus theory. A fourth pretest, an application task, required participants to study a diagram of a projectile shot from a cannon, label the path the projectile would take, and explain the reason for their choice of path.

Two of three posttests were administered immediately after the treatment and again after a two-month delay. The first posttest was a 21-item true-false test. The second was the application task described earlier. The third posttest, an 6-item short-answer test, was administered only one time, immediately after the treatment. Examples of items from the short-answer test include the following:

(1) A person is walking forward at a brisk pace carrying a stone at shoulder height. Explain, according to Newton's theory, where the stone would fall in relation to the point where it was dropped.

(2) Why would this happen?

(3) Explain why an object stops or changes direction.

Attitude questionnaire. We also investigated these prospective teachers' attitudes toward science, using a 16-item questionnaire designed to elicit responses to questions about (a) the number of science courses they had taken; (b) their beliefs about the importance of science in general and physics in particular; and (c) their attitudes toward and experiences with teachers, textbooks, demonstrations, formal instruction, and informal learning experiences. Participants were directed to rate issues of importance and attitudes on a five-point Likert scale, but were also asked to write explanations for each item rated.

Videotaped teaching and post-teaching interview. To obtain qualitative documentation of prospective teachers' ideas about Newtonian principles after instruction, 16 prospective teachers were videotaped as they taught concepts of motion to a fifth-grade student. They were later interviewed, using a 10-item structured interview form designed to encourage them to reflect on their teaching of the physics principle in the videotaped one-on-one teaching session. As the interviewer audiorecorded their responses to each item on the interview form, participants were asked to rate and explain their level of knowledge, comfort in teaching, and success in teaching the targeted physics principle. They were also asked to discuss the influence of the instruction they had received in helping them to teach the concept.

Procedure

The study was conducted in four phases. In phase one, the test of relatedness, the test of appropriateness, the 10-item true-false test, and the application task were used as pretests to determine these prospective teachers' levels of prior knowledge about Newton's first law of motion, their ability to apply that law, and their non-scientific conceptions about motion. Only those who held non-scientific notions were retained in the study. Participants were considered to have non-scientific notions if they chose the wrong path for the projectile in the application pretest and/or gave the wrong explanation for the projectile's path. If the correct path were chosen and a borderline explanation were given, key items reflecting general principles were reviewed on the multiple choice test.

In phase two, the prospective teachers were assigned to one of four treatment groups representing the two levels of prediction/demonstration (Demo/No Demo) and two levels of usefulness (Told/Not Told). Participants were required to attend a one-on-one (researcher and participant) session that lasted 50-60 minutes. Members of the Demo/Told group were informed in writing about the forthcoming videotaped lesson at the beginning of the one-on-one session. Next, they participated in several demonstrations of Newton's first law of motion, in which they made predictions and then compared those predictions to the outcomes of the demonstrations. They also read the 1-page refutational stimulus text on Newton's theory of motion, worked on a buffer activity to control for the effects of short-term memory, and completed the short-answer test, the 21-item true-false test, and the application task (diagram). Except for *not* being told about the videotaped teaching session that would follow in phase three, subjects in the Demo/Not Told group participated in the same activities as those in the Demo/Told group. In order to control for time, participants in the No Demo/Told and No Demo/Not Told groups worked on word search puzzles that contained words taken from the stimulus text in lieu of the demonstrations. They, like the other two groups, then read the stimulus text and completed the posttests, finally, all four groups of prospective teachers were given the attitude questionnaire to complete after the session.

In phase three, 8 randomly selected participants who had been told they would use their newly acquired information in an actual lesson were videotaped as each of them individually taught a fifth-grade student. Four came from the Demo/Told group and four from the No Demo/Told Group. Another randomly selected 8 participants who had not been told they would use the information in an actual lesson were also videotaped as each of them taught a fifth-grade student. Four were from the Demo/Not Told group and four were from the No Demo/Not Told group. As the participants entered the room where they would teach, they were provided with a set of materials that they could use if they liked, but they were not given time to prepare a lesson. We allowed no preparation time because we wanted to reduce the possibility that some participants would prepare elaborate lessons reflecting non-treatment information rather than information received from the treatment. Participants were

assured that no one else was allowed to prepare and that their level of preparation would not be judged. They were also told that they could have as much time as they wished to explain the concept. Audiotaped interviews were held with each of the 16 prospective teachers following their videotaped lessons. The fifth-grade students were asked to rate how effective they thought these prospective teachers had been in helping them learn about Newton's first law of motion.

In phase four, approximately two months after the initial lesson, the true-false test and the application task administered in phase two were re-administered as delayed posttests.

Scoring and Interpreting Data

Pre- and posttests. We scored each of the pretests and posttests without knowledge of the group membership of the prospective teachers in all experimental conditions. Scores on all measures except the short-answer test and the application task were obtained by comparing participants' responses to the responses on a prepared answer key. One point was awarded for each correct match. We read the responses to the six-item short-answer test and awarded one point to each correctly answered question except for questions #2 and #4, which received one or two points because these answers had two parts. The application task scores ranged from zero to two. Full credit was awarded if participants correctly labeled the path the projectile would take *and* gave the correct explanation for their choice of paths. One point was awarded if participants *either* correctly labeled *or* explained the path the projectile would take, and no points were awarded if both the label and the explanation were incorrect.

Attitude questionnaire. Using data from the 16-item questionnaire, we tabulated participants' beliefs about the importance of science in general and physics in particular, their level of knowledge about these topics, their attitudes, and their feelings about the influence of teachers, text, formal instruction, and informal experiences. Where rating scales were not used (on items about teachers, text, formal instruction, and informal experiences), each written answer was rated as negative, neutral, or positive and assigned a score of 1, 2, or 3, respectively. In addition, the questionnaires from the 16 participants who were videotaped teaching were separated from the other questionnaires and the explanations that the participants supplied to supplement their ratings were analyzed descriptively.

Videotaped lessons. We viewed, transcribed, and coded the 16 videotaped lessons and the post-teaching interviews. The analysis consisted of looking for evidence of an overall correct explanation of the physics principle that had been taught, noting the length of the lesson, and noting the self and fifth-graders' ratings of the teacher. These data are shown in Table 4.

Another researcher viewed each of the videotapes and read the transcriptions in order to discover patterns not previously identified. She noted that the teachers often appeared to hold seemingly contradictory ideas, so that only part of what they explained to their fifth grade student was correct. With that observation in mind, she then analyzed the demonstra-

tions, the text, and all test items for discrete concepts of motion, that is, concepts that could be held independently of others. Four concepts were identified. Concept 1 was that a horizontally propelled projectile's path will form an arc on its way to the ground. Concept 2 was that something that is carried (in motion) and released will maintain its forward motion. Concept 3 was that horizontal motion and gravity are both factors affecting the path of the projectile, which explains why the object moves in an arc rather than first going out and then down. Concept 4 was that these forces are external to the projectile: that is, changes in motion are brought about by external forces rather than internal ones. All of these concepts were introduced in both the demonstration and in the text and were tested as well. Once these discrete concepts were identified, all data records of the 16 videotaped participants (pretests, posttests, videotaped lesson, structured interview, and delayed posttests) were coded for evidence that these prospective teachers either had or did not have these concepts. In the case of the true-false and other forced-choice items, only a lack of the concept could be documented, because a participant could choose a scientific answer by chance. In the open-ended questions, the videotaped lessons, and the interviews, scientific and non-scientific principles could be noted if they were mentioned. Although we had no way of knowing whether or not a teacher was holding a scientific principle but not sharing it with us, we could trace an identified non-scientific conception from pre- to posttest and from posttest to delayed posttest. The contents of the videotaped lessons and structured interviews provided us with informal opportunities to view these prospective teachers' thinking about the targeted concepts and to note if (and sometimes why) these concepts changed during the course of the study.

To interpret the data, we arranged the coded items on a matrix for each teacher (Miles & Hubermann, 1984). The matrix showed the sequence of tasks from pretest to delayed posttest and Non-Scientific conceptions (from forced choice and open-ended items) and Scientific (from open-ended items) conceptions. Each concept was written in the proper box and color-coded so that the category of the content (1-4) could be easily identified and traced across the sequence. If a change from a previous concept was noted during the videotaped lesson or structured interview, the behavior preceding or explaining the change was also noted, if identified. We also placed scores from the pre- and posttests in the matrix. From these individual matrices, we descriptively analyzed (a) how many categories of non-scientific concepts were held by teachers at the start and end of the study, (b) which non-scientific concepts were originally more often observed, (c) which non-scientific concepts seemed to be more or less readily replaced by scientific ones, and (d) what behaviors or observations seemed to explain changes either from non-scientific to scientific thinking or vice versa. Appendix A shows examples of these matrices, except that symbols replace the color-coding.

Finally, all the data on two of the prospective teachers who were videotaped were analyzed qualitatively. In each analysis, we attempted to describe the interaction of variables

that resulted in these teachers' level of conceptual change at the end of the study.

RESULTS AND DISCUSSION

In this section, we present findings in two ways. For the quantitative part of our study, we present the results for each source of data and then discuss the findings. For the observational and qualitative part of our study, we present, in a more integrated fashion, our interpretations along with the data which led us to those interpretations. In a subsequent section, we discuss in a general way the cumulative findings of the entire study.

Analysis of Posttests

To see if possible group differences existed prior to instruction, four one-way analyses of variance were run on each of the pretests. None of the groups differed significantly on the appropriateness pretest, $F_{(3,69)} = 1.27$, $p = .29$, the relatedness pretest, $F_{(3,69)} = 0.72$, $p = .54$, the T/F pretest, $F_{(3,69)} = 0.64$, $p = .59$, or the application pretest , $F_{(3,69)} = 1.73$, $p = .17$.

The posttests were then analyzed using either analysis of covariance or analysis of covariance with repeated measures. A 2 (Demo/No Demo) X 2 (Told, Not Told) completely-crossed design was used. The relatedness pretest, which resulted in the greatest reduction of the error variance, was the covariate for the posttests. An analysis of covariance was run on the 73 observations obtained for the short-answer posttest. Separate analyses of covariance with repeated measures were conducted for the immediate and delayed true-false and immediate and delayed application task posttests. Absenteeism at the time of the delayed tests resulted in our dropping 6 of the 73 subjects from the analyses. Consequently, immediate and de layed posttest measures for the true-false and application tasks were analyzed using data from 67 subjects. Tables 1, 2, and 3 present the adjusted means and standard deviations by group for each of the posttests.

Short-answer posttest. The analysis of covariance on the short-answer posttest revealed no statistically significant interaction between Told and Demo, $F_{(1,68)} = 2.80$, $p = .10$. There was a statistically significant main effect for Demo, $F_{(1,68)} = 7.34$, $p = .01$, in favor of the group that participated in the prediction/demonstration, but not for Told, $F_{(1,68)} = 0.68$, $p = .42$. Effect sizes were calculated by expressing mean differences between the Demo and No Demo groups in standard deviation units (see Glass, McGraw, & Smith, 1981). On the main effect for Demo, $R^2 = .14$, with an effect size of .64.

Immediate and delayed true-false posttests. The analyses of covariance with repeated measures on the true-false posttests revealed no statistically significant interaction between Told and Demo on either the immediate, $F_{(1,62)} = 0.41$, $p = .53$, or delayed, $F_{(1,62)} = 0.67$, $p = .42$, true-false posttests. There was a statistically significant main effect for Demo, $F_{(1,62)} = 5.85$, $p = .02$, in favor of the group that participated in the demo on the immediate true-false posttest, but not on the delayed true-false posttest, $F_{(1,62)} = 0.43$, $p = .52$. There were no statistically significant main effects for Told on either the immediate, $F_{(1,62)} = 1.11$, $p = .30$, or the delayed, $F_{(1,62)} = 0.79$, $p = .38$,

Table 1. Adjusted Means (*M*) and Standard Deviations (*SD*) by Group on Short-Answer Posttest

Group	Number	Adj. Means	(Standard Deviations)
Demonstration	39	6.65	(1.38)
No Demonstration	34	5.76	(1.39)
Told	36	6.07	(1.37)
Not Told	37	6.34	(1.53)

Highest possible score = 8

Table 2. Adjusted Means (*M*) and Standard Deviations (*SD*) by Group on Immediate and Delayed True/False Posttests

Group	*Number	Immediate		Delayed	
		M	(*SD*)	*M*	(*SD*)
Demonstration	33	18.56	(1.74)	16.78	(2.56)
No Demonstration	34	17.48	(2.26)	16.39	(2.32)
Told	34	17.78	(2.33)	16.32	(2.65)
Not Told	33	18.27	(1.78)	16.85	(2.20)

*In repeated measures analysis, observations with missings values are not used.

Table 3. Adjusted Means (*M*) and Standard Deviations (*SD*) by Group on Immediate and Delayed Application Posttests

Group	*Number	Immediate		Delayed	
		M	(*SD*)	*M*	(*SD*)
Demonstration	33	1.70	(0.57)	1.58	(0.56)
No Demonstration	34	1.17	(0.76)	1.38	(0.70)
Told	34	1.48	(0.74)	1.48	(0.66)
Not Told	33	1.39	(0.69)	1.48	(0.62)

*In repeated measures analysis, observations with missing values are not used.

true-false posttests. On the main effect for Demo, $R^2 = .11$, with an effect size of .48.

Immediate and delayed application task. The analyses of covariance on the application task revealed no statistically significant interaction between Told and Demo on either the immediate, $F_{(1,62)} = 1.07$, $p = .31$, or the delayed, $F_{(1,62)} = 0.79$, $p = .38$, application tasks. There was a statistically significant main effect for Demo, $F_{(1,62)} = 10.09$, $p = .005$, in favor of the group that participated in the prediction/demonstration on the immediate application task, but not on the delayed application task, $F_{(1,62)} = 1.87$, $p = .18$. There were no statistically significant main effects for Told on either the immediate, $F_{(1,62)} = 0.25$, $p = .62$, or the delayed, $F_{(1,62)} = 0.00$, $p = .99$, application tasks. On the main effect for Demo, $R^2 = .18$, with an effect size of .70.

Discussion of Posttest Results

The posttests were analyzed in order to provide answers to the following questions: (a) Will participating in a prediction/demonstration condition before reading a text allow prospective teachers to relinquish their non-scientific conceptions in favor of scientific ones? (b) Will telling prospective teachers that they will be required to teach a student improve learning of the concept? Because all the participants had non-scientific conceptions, we assumed that if a scientific concept had been learned, conceptual change had taken place. We tested both the immediate and the delayed effects of the prediction/demonstration (Demo/No Demo) condition and the usefulness condition (Told/Not Told).

Prediction/Demonstration Condition. Prospective teachers who made predictions and saw demonstrations before reading a text did significantly better than the read-only groups on all three of the immediate outcome measures. This finding supports Marshall's (1989) findings in her study of prospective elementary teachers, that the combination of demonstration and reading produced the greatest change in subjects' understanding of the causes of seasonal change. The effectiveness of combining prediction/demonstration and reading in the present study also partially replicates Swafford's (1989) findings in her qualitative analysis of data obtained from high school students who had naive conceptions about either free-falling objects or the cause of seasonal change.

After two months had elapsed, however, it was impossible to distinguish between participants in the Demo and No Demo groups, at least as measured by their performances on the delayed true-false and application tasks. The lack of posttest differences after two months does not mean, however, that participants necessarily failed to change their conceptions in the long term. In a post-hoc 2 (Demo/No Demo) x 2 (posttest/delayed posttest) split-plot ANOVA, where Test consisted of application pretest and application delayed posttest, we found that although the effects of prediction/demonstration were non-significant, there were significant differences between pretest and delayed posttest scores, $F_{(1,65)} = 109.75$, $p < .001$, on the application task. This indicated to us that the prospective teachers did change their previous ideas about motion, regardless of whether they were in the Demo

Table 4. Means of Delayed Multiple-Choice and Application Tests for High and Low Ratings of Knowledge, Attitude, Importance, and Usefulness

	Knowledge		Attitude		Importance		Usefulness	
	5+	<5	5+	<5	5+	<5	+	–
Multiple Choice	19.5	18.4	18.9	16.0	17.3	18.7	18.6	15.8
Applications	1.5	1.3	1.6	1.0	1.3	1.4	1.6	1.2
N	4	12	7	8	12	3	5	5

or No Demo group. Further, there was no significant loss of concepts for either the Demo or No Demo groups on the true-false delayed posttest when compared to the immediate posttest, $F_s < 2$).

Our interpretation of these results is that some long-term conceptual change occurred. Because the text was the only other factor experienced by all groups, we speculate that the text, rather than the prediction/demonstration, may have helped solidify concepts in the long run. The effect of prediction/ demonstration lessened over time, but the effect of text remained. The long term benefits of text versus demonstration should be the focus of subsequent research.

Told Condition. In our study, attempting to manipulate the usefulness of the information to be learned had no effect on subsequent learning. The idea that a concept must appear useful has been theoretically linked to the notion of conceptual change (Posner, et al., 1982). Therefore, we had anticipated that giving elementary education majors advance information of an impending teaching assignment would increase motivation to learn the physics principle. That it did not produce the desired effect might be explained in several ways.

One explanation is that telling prospective elementary teachers they would have to teach the physics principle produced anxiety, counteracting any potential increase in motivation. Alternatively, perhaps the teachers did not believe they would really be called on to teach a physics principle to an elementary school student. A more likely possibility, however, is that all of the participants in both the Told and Not Told groups were already motivated, and any attempt to increase motivation by making the information useful was superfluous. Prospective teachers have surely internalized the idea that achievement in school is important. Thus, they may have been motivated to achieve under any circumstances, and increasing a topic's usefulness, in the sense of merely being able to explain a concept, may have had little bearing on their motivation. Indeed, it was Posner, Strike, Hewson, and Gertzog's (1982) original idea that usefulness implied the ability to help one solve future problems rather than the ability to do well on tests or explanations.

Therefore, our usefulness condition may have been inadequate to test the notion we proposed to test.

Analysis of Attitude Questionnaire

From the questionnaire we found that:

(1) Participants' attitudes about science were somewhat neutral when the field was considered as a whole. On a 10-point scale, $M = 5.38$. When other science courses and physics were separated, however, participants reported liking the other sciences more than physics. For physics, $M = 3.6$. For example, 10 of the 16 teachers who were videotaped liked science but did not like physics. Comments such as "I don't feel like I will ever have to use it" and "too much computation..." typified comments made about physics.

(2) Most participants felt uncomfortable with their knowledge about the sciences in general and physics in particular. When the other sciences and physics were considered together, students rated their knowledge as being somewhat low. On a 10-point scale, $M = 4.28$. They rated their knowledge of physics lower still, $M = 2.2$.

(3) Generally, participants felt that science was important to study. On a 10-point scale, $M = 7.14$. This was also true of physics. They rated the importance of physics just as high, $M = 7.15$, as the other sciences. Although participants' ratings were high, their comments revealed less enthusiasm. Of the 16 videotaped teachers, for example, five discussed the importance of science as useful in the world, and four made those comments about physics. The other participants, however, either made general comments like "everyone should be exposed to it (physics)" or made negative comments, such as "I don't feel like I will ever have to use it." Although only one person made negative comments about the importance of science, there were eight such comments about the irrelevance of physics.

(4) The prospective teachers disliked science textbooks. The mean rating on a 3-point scale was 1.67, with 1 being negative, 2 being neutral, and 3 being positive. Of the 16 teachers who were videotaped, 12 of the 16 had negative things to say. They thought science textbooks were boring, hard to understand, irrelevant, and unnecessary.

(5) The teachers liked demonstrations and experiments. The mean rating on a 3-point scale was 2.82 with 1 being negative, 2 being neutral, and 3 being positive. Only two students of the 16 videotaped teachers objected to them.

(6) Most of the participants had neutral to negative formal experiences in science classes. The mean rating on a 3-point

scale was 1.57. Students cited the teacher, the text, and the assignments as sources of their negative feelings.

We contrasted the delayed posttest results of those who rated high and low in knowledge, attitude, importance, and usefulness. These data are presented in Table 4. In every case except importance, those who rated themselves higher did better on the delayed multiple choice and application tests than those who rated themselves lower.

Discussion of Attitude Questionnaire Results

We originally initiated the analysis so that we could discover what influences prior experiences and attitudes have on the learning of counterintuitive science concepts. Many prospective teachers had endured negative experiences with physics and disliked science texts, preferring demonstrations. Despite these negative feelings, however, they still felt that science, including physics, was important to learn. This belief in the importance of science supports the explanation advanced earlier that the participants in this study were already motivated to learn the scientific concept we tried to teach them. Our feeling is that, despite their motivation to learn, most of the prospective teachers we worked with found the concept we taught difficult. Their overall neutral attitudes about science and more negative attitudes about physics may partially result from their perception that science, and particularly physics, is difficult as well as from negative experiences. The sentiment that "I know I should learn it, but I don't like it" was expressed in several instances, and we believe this feeling prevailed in most participants. In support of this belief, we note the participants' lack of confidence in their knowledge of science, especially physics. The attitudes of these prospective teachers corroborate findings from Pratt (1981) and Lederman and Gess-Newsome (1991), cited earlier, who argued that teachers' lack of comfort in teaching science results from feelings of unpreparedness and lack of understanding.

Further, the type of motivation for learning that we observed some students had ("I know I should learn it") stems from expectations they perceived others as having for them, reflecting extrinsic rather than intrinsic motivation. Although a few participants expressed the sentiment that they believed physics would improve their ability to deal with their physical world, the majority of participants did not. Perhaps many of these prospective teachers were not really convinced of the usefulness of the concept in the sense of it helping them to solve future problems. More conviction might lead to more intrinsically motivated behavior.

On a positive note, however, the fact that some long-term learning, as evidenced by delayed posttest results, occurred despite only neutral attitudes and negative experiences is encouraging. This finding of learning in the face of some negative attitudes supports the findings of other researchers who discovered that attitudes explain only a small to moderate part of the variation in science learning (Schibeci, 1989; Talton & Simpson, 1987). Our finding is significant in that it documents this effect with *conceptual change* rather than overall science achievement.

Analysis and Discussion of Videotaped Lessons and Post-Lesson Interviews

The analysis of the videotaped teaching and interviews was initiated to help answer the following questions: (a) What changes in thinking do prospective teachers evidence as they are taught a counterintuitive scientific principle? (b) What influences do other factors have in these changes? Our analysis revealed that prospective teachers who participated in the prediction/demonstration activity and also taught a videotaped lesson scored higher than the other videotaped teachers on the delayed posttests. As indicated in Table 5, participants in the two Demo groups had higher mean scores than those in the two No Demo groups on the following post-lesson interview measures: self-rated knowledge level, Demo M = 5.25, No Demo M = 4.12; self-rated success level, Demo M = 6.12, No Demo M = 4.50; and fifth-graders' ratings of teachers' success, Demo M = 7.56, No Demo M = 6.38. Seventy-five percent of the prospective teachers in the Demo groups were judged by the researchers to have taught the concept of projectile motion correctly as compared to only 50% of the subjects in the No Demo groups. Similarly, 87.5% of the teachers in the Demo groups indicated in the post-lesson interview that they knew they had taught the concept correctly, whereas only 37.5% of the teachers in the No Demo groups indicated this to be the case. We also observed that the teachers in the Demo groups used the same demonstrations in which they had previously participated. On the immediate and delayed posttests, the teachers in the Demo groups outperformed those in the No Demo groups on every measure: short-answer, Demo M = 6.25, No Demo M = 5.50; true-false immediate, Demo M = 18.12, No Demo M = 17.00; true-false delayed, Demo M = 17.14, No Demo M = 17.00; application task immediate, Demo M = 1.50, No Demo M = 0.88; and application task delayed, Demo M = 1.43, No Demo M = 1.12.

It appears that some concepts were more difficult than others. (The results of our analysis of the data placed into the matrices are presented in Tables 6 and 7). The most intuitive concept for prospective teachers may have been that the path of a projectile is an arc. Only 9 of the 16 missed items about the arc at the beginning of the study. By the end of the study, no one missed these items. Two ideas that appeared difficult at the beginning of the study were the idea that a carried object maintains its forward motion if dropped and that forward motion and gravity operate simultaneously. Everyone missed items about forward motion and simultaneity at the beginning of the study. Ten of the 16 (4 who saw the demonstrations and 6 who did not) still missed items about forward motion by the end of the study and 5 (1 who had seen the demonstration and 4 who did not) still missed items about simultaneity. The last concept was also difficult. Fourteen of the 16 missed items about external force at the beginning of the study. By the end, 10 (5 who had seen the demonstration and 5 who had not) were still missing those items.

Everyone at the beginning of the study held non-scientific conceptions, and, of the 16 who were videotaped, only 2 answered all items

Table 5. Summary Data for Videotaped Teaching Lesson

Subject Number & Name	Group	Length of Video Lesson	# Science Courses	Self-Rated Knowledge Level	Self-Rated Success Level	5th Grader's Rating
# 14 - T. O.	T/D	3	4	7	7	8
# 15 - D. L.	T/D	6	6	6	8	8
# 16 - S. K.	T/D	7	5	5	8	8
# 13 - E. T.	T/D	4	4	7	9	8 1/2
# 33 - E. Z.	T/ND	6	5	3	7	6
# 34 - K. M.	T/ND	4	4	2	6	8
# 35 - E. H.	T/ND	6	4	1	1	5
# 36 - B. C.	T/ND	4	4	8	5	7
# 37 - L. R.	NT/D	7	7	8	5	8
# 38 - P. B.	NT/D	1	6	0	2	6
# 39 - M. M.	NT/D	3	6	7	5	6
# 40 - J. S.	NT/D	4	6	2	5	8
# 57 - C. S.	NT/ND	4	7	3	6	7
# 59 - L. F.	NT/ND	3	6	1	1	6
# 61 - C. C.	NT/ND	4	6	7	8	9
# 58 - S. W.	NT/ND	2	4	8	2	3

correctly at the end. Both began the study with non-scientific ideas about all four of the targeted concepts but with high knowledge and importance ratings. One specifically noted the usefulness of physics in understanding the world. If these participants had rather solidified intuitive concepts (in that they began the study with naive notions about all four targeted concepts), it is intriguing to speculate what allowed them to change them. Perhaps they experienced more conflict between previous and new notions, and were therefore impelled to overcome cognitive dissonance, especially considering their positive feelings about science. We looked at the means of the delayed multiple-choice and application posttests to see

Table 5. Summary Data for Videotaped Teaching Lesson *continued*

Correct Concept In Lesson	Correct Concept In Interview	Short Answer Posttest	T/F Immediate Posttest	T/F Delayed Posttest	Application Immediate Posttest	Application Delayed Posttest
NO	YES	6	17	20	2	2
YES	YES	8	18	19	2	2
YES	YES	5	19	16	2	1
YES	YES	6	21	-	1	-
NO	NO	5	18	15	0	0
NO	NO	4	19	19	1	1
YES	YES	4	15	16	1	1
NO	NO	5	12	14	0	0
YES	YES	8	20	20	2	2
NO	NO	6	13	12	0	0
YES	YES	8	19	17	2	2
YES	YES	3	18	16	1	2
YES	YES	8	20	19	1	2
NO	NO	6	14	14	1	1
YES	YES	6	19	20	1	1
YES	NO	6	19	19	1	1

if those having more non-scientific notions evidenced more conceptual change. Participants who missed items reflecting all four concepts did better on those posttests, (N = 7; multiple choice *M* = 18.3; application test *M* = 1.7), than those who missed items reflecting three or fewer concepts, (N = 8; multiple choice *M* = 16.4; application test *M* = 1.7). Further, no one who missed four concepts referred to physics as being irrelevant.

Conceptual change often occurred in a piecemeal fashion. Several prospective teachers learned scientific concepts but also retained some seemingly incompatible ideas. Four of the 16 (two who participated in the prediction/demonstration and two who did not) believed

in both external and internal forces as a result of the study. Three of the four students attributed movement to external forces only and relegated internal force to one that did not control what an object did (much like the concept of potential energy). The fourth became confused when her demonstration did not go as planned. She then explained that cargo dropped from a plane would go wobbly or curve because of the forward force, but that a force goes "up, in the ball" so that it can't be seen. These four teachers, on the attitude questionnaire, rated their knowledge of physics as extremely low (1-2). Further, only one had a positive attitude about physics. And while two teachers believed it was important to study physics, two others made explicit comments about physics' lack of usefulness. Another prospective teacher believed that the weight of the object would somehow determine whether or not the path of an object formed an arc. During the videotaped teaching lesson, this participant dropped a bottle during a demonstration, and it did not go forward as she had predicted (She twisted her hand backward as she released it). During the structured interview, she expressed the idea that it must have been too heavy. This teacher had a high level of perceived knowledge as well as better than average attitude and importance ratings. Further, she believed that physics knowledge was useful.

A possible explanation for the appearance of new non-scientific conceptions is that these prospective teachers were merely trying to assimilate the new notion of external force into their prior notions of internal force and did not, then, restructure their thinking (Hewson & Hewson's [1984] idea of conceptual capture). However, their explanations of these forces did reveal some restructuring, in that they relegated the notion of internal force to something that had little bearing on motion. These teachers seemed to become confused in their attempts to reconcile previous notions with new ones and to reconcile what they had learned from instruction with the incompatible (and erroneous) observations they made while teaching (when their demonstrations did not go as they had believed they would). Those who ended up believing in internal as well as external forces may have experienced what Nissani and Hoefler-Nissani (1992) observed in their scientists who were exposed to conflicting theoretical and experimental results: they adjusted their observations to fit their expectations. Although four of the five teachers who became confused had lower knowledge, attitude, and importance ratings than others, it seems that high levels of perceived knowledge and a good attitude did not guarantee that the one teacher would gain a purely scientific understanding. In attempting to make sense of conflicting data, some people may generate new, non-scientific notions.

The participants in the videotaped teaching seemed to exchange one non-scientific concept for another, relinquishing non-scientific conceptions and adopting new ones throughout the study, not just as an immediate result of instruction. Because we could detect no pattern in this process, we contrasted the knowledge, attitude, and importance ratings of the four students who gained in scientific knowledge, the three students who lost scientific knowledge, and the seven students who seemed to

Table 6. Summary of Matrix Data: Number of Students Evidencing Non-Scientific Conceptions

	Pretest	Posttest	Videotape/ Interview*	Delayed Posttest
Arced Path	9	4	1	0
Forward Motion	16	11	2	10
Simultaneity	16	6	3	5
External Forces	14	6	4	10

*Prospective teachers may have maintained non-scientific conceptions during this phase without their being detected.

gain, then lose, scientific knowledge between the immediate posttest and delayed posttest. For the students who gained in knowledge, their mean ratings were 3.5, 4.0, and 5.6 for knowledge, attitude, and importance, respectively, with a total of 13.2 out of 30 possible rating points. All but one of these students made comments on the questionnaire about the usefulness of physics for understanding the world (the exception also had low knowledge, attitude, and importance ratings that brought down the average). For the students who lost knowledge, their mean ratings were 2.33, 4.0, and 3.33, respectively, with a total of 9.7 rating points out of 30. One of the students mentioned the usefulness of physics and the other two did not. The seven who appeared to gain then lose scientific knowledge, had mean ratings of 2.0, 3.6, and 6.7 for knowledge, attitude, and importance, respectively, with a total of 12.3 rating points out of 30. Only one student of the seven mentioned that information about physics was useful. We hypothesize that a combination of knowledge, attitude, and importance factors are responsible for much of the fluctuation we noted. Further, belief in the usefulness of physics may lead to conceptual change. The nature of this combination should be tested in more controlled conditions with more participants.

Two In-Depth Analyses

We chose two participants for in-depth analyses, one from a Demo treatment group and one from a No Demo group. Both had been members in the group of 16 participants randomly selected to teach the videotaped lessons. We chose them because they appeared to be representative of participants who changed and did not change their notions about the targeted physics principle. D. L. appeared to have a better understanding of Newtonian explanations for physics principles at the time of the delayed posttest, while B. C. showed almost no movement in ideas from pretest to

Table 7. Number of non-scientific conceptions of individual prospective teachers.

	Pretest	Posttest	Videotape/Interview	Delayed Posttest
E.T.	4	0	1	0
T.O	4	3	2	1*
D.L.	3	2	0	1
S.K.	4	2	1	2
E.Z.	3	2	2	2*
K.M.	3	0	1	1
E.H.	3	3	1	3*
B.C.	4	3	1	3*
L.R.	4	0	0	0
P.B.	3	3	0	2
M.M.	4	1	1	2*
J.S.	3	2	0	3*
C.S.	4	1	1	1
L.F.	3	3	1	3
S.W.	2	1	0	1
C.C.	3	1	0	0

*Switched from one non-scientific conception to another between posttest and delayed posttest.

delayed posttest. We analyzed the behavior of these two participants to examine the interaction among variables that accounts for the fact that some adopt scientific conceptions and some do not.

What factors accounted for D. L.'s understanding and B. C.'s lack of it? It is possible that being in a prediction/demonstration group was beneficial to D. L. When D. L. taught the lesson to a fifth-grader, she used the examples from the demonstration and commented on the demonstration's helpfulness. D. L., it appears, also had the advantage on several of the factors other than instruction that are believed to be important in producing conceptual change. For one, D. L. had a firm grounding in science, having taken six courses. It is possible, then, that she had internalized a scientist's view of the nature of scientific knowledge. Epistemological variables, indeed, are believed to account for some of the variation in understanding content (Schommer, 1990; Strike & Posner, 1992). D. L. also had a positive attitude toward physics and believed

that physics was important and useful. Strike and Posner (1992) base much of their work on observations that students who learn physics principles do so because they believe that physics gives them "reliable and objective knowledge of the real world" (p. 11). D. L. appeared to have this view. finally, D. L. recognized that she had previously held naive conceptions about motion. In her interview, she discussed how she had initially made wrong predictions, and she commented on how the demonstrations had helped clarify her misunderstandings. If, as Posner et al. (1982) argue, students must first be dissatisfied with their current conceptions for conceptual change to occur, then D. L. demonstrated this dissatisfaction. Only two other people in the study reported experiencing conceptual conflict. Both also evidenced considerable change in concepts.

B. C. had none of the advantages D. L. had. For example, she lacked a firm grounding in science or physics and exhibited a neutral attitude towards them. She did not have the benefit of participating in the demonstration group, and she learned little from reading. During the interview, B. C.'s stated motivation for learning was to get the right answers, a fairly low-level form of motivation. During our discussions with her, we saw no evidence that B. C. was ever confronted with the notion that her previous understandings were not in line with Newtonian principles. In fact, she rated her knowledge as high after incorrectly teaching about Newton's laws of motion. We believe that B. C. chose not to confront her existing notions, which would have led to conceptual exchange (Hewson & Hewson, 1984), and either rejected or tried to memorize the new ideas, despite reading refutational text designed to foster conceptual conflict.

CONCLUSION

In this study, we investigated the conditions under which prospective elementary school teachers might be expected to relinquish nonscientific conceptions about projectile motion. From a research perspective, the present study's findings are important in that they replicate earlier work on the effectiveness of combining demonstration with reading to help students learn counterintuitive science concepts. However, the absence of a statistically significant retention effect for the instructional treatment implies the need for further study. Although we did find long-term learning of the targeted principles, after two months time the effect of demonstration was no greater than the effect of merely reading the text. The fact that conceptual change did occur just by having students read, however, is encouraging and corroborates the effectiveness of refutational text documented by Guzzetti, Snyder, Glass, and Gamas (1993) in their meta-analysis.

Telling prospective teachers in advance of a forthcoming teaching assignment may be an inadequate motivator. At least in the present study, this advance warning did not cause students to change their naive conceptions about motion. Perhaps experimental conditions that are more intrinsically rewarding are needed to motivate prospective elementary teachers to relinquish erroneous notions about complex science concepts.

Our analysis of the videotaped teaching sessions and the in-depth analysis of two participants' test responses and teaching performance support the notion that a complex interaction of factors is responsible for conceptual change. Our qualitative data suggest that perceived knowledge and belief factors account for what is not explained by instruction, and that there may be differences between students who learn physics because they believe it will help them understand the world and those who learn physics because they want to get the right answers. The interaction of perceived knowledge and intrinsic motivation should be studied further as should the epistemological basis of conceptual change. We also observed that teachers who evidenced more non-scientific ideas were more likely to change their ideas than those evidencing fewer non-scientific ideas. What influenced those who did change to learn scientific ideas? Did they experience more dissonance?

Although researchers believe cognitive dissonance is a necessary factor in conceptual change (e.g., Strike, Posner, Hewson, & Gertzog, 1982), the participants' apparent attempts to make sense of the difference between the targeted scientific concept and their own prior and present experiences seemed to sometimes lead them to other non-scientific conceptions. In other words, the prospective teachers we observed may have restructured their previous notions, though not in the direction we had hoped. This dynamic nature of conceptual change and the role of conceptual conflict or cognitive dissonance should be further explored. Whether or not cognitive dissonance is a necessary prerequisite to conceptual change is still not clear. While participants who expressed cognitive conflict and those with more naive ideas about motion (hence possibly experiencing more cognitive conflict) were successful in adopting scientific explanations for the concepts presented, cognitive dissonance may have led others to adopt new non-scientific understandings. Creating cognitive conflict is a common part of many successful instructional techniques (Hynd & Guzzetti, in press), but documenting that cognitive conflict has occurred is problematic. If we ask research participants if they experienced conflict, we may be predisposing them to answer that they had. If we do not ask, they may experience conflict but fail to report it. In this study, only three of the sixteen teachers volunteered that they had experienced conceptual conflict. Were these students more metacognitively aware? Is awareness of conflict as necessary as the conflict itself?

On a final note, teacher educators should be aware that prospective elementary school teachers hold non-scientific conceptions and with good reason feel uneasy about their level of knowledge in physics. It is disturbing to think they may, in turn, teach these non-scientific concepts to their students. Perhaps programs aimed at educating prospective teachers about the nature of conceptual change would help them to become more aware of their own attempts to reconcile conflicting information, hence increasing the likelihood that they will exchange non-scientific beliefs for scientific ones and promote the same kind of change in their students. Prospective teachers could be taught current theory about conceptual change and the role of conceptual conflict, bridging

analogies, and integration in learning, and they could be encouraged to incorporate these components into science lessons and observe their effects. Further, prospective teachers could learn about alternate forms of text, such as refutational text, perhaps rewriting short sections of text on counterintuitive topics in refutational style. They could also be encouraged to observe and take into account motivational and social factors that may influence students' will to change concepts, and to be more observant of the evolution of students' thinking.

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Appendix A. Examples of Matrices

Name: P.B. Condition #: 3B (Demo/Not Told)		Non-Scientific Conceptions	Scientific Conceptions
Pretest Info & Scores			
HS & College Science Courses	6	Lack of forward motion (carried, tossed) > Simultaneity = Inner force (launched) ●	
True/False Test	3/10		
Application	1/2		
Post Demo Info & Scores			
True/False Test	13/21	Lack of forward motion > Simultaneity = Inner force (launched) ●	2 directions out and down (launched)
Application Test	0/2		
Short Answer Test	6/8		
Mini-Lesson	1/10		
Attitude Questionnaire	Knowledge 3 Attitude 2 Importance 8.7 Usefulness —		
Video Lesson Info & Scores			
Knowledge	0/10	Just guess, 'cause I don't have the answer either.	
Teaching	2/10		
Student Rating	8/10		
Interview		(Didn't pay attention to treatment. Didn't know she'd be called on.)	Two forces, forward motion and gravity causes things to move to earth =
Delayed Posttest Info & Scores		Lack of forward motion > Inner force (launched) ●	
True/False	12/21		
Application	0/2		

⌒ Arced path
> Forward motion
= Simultaneity
● Inner force

Appendix A. Examples of matrices *continued*

Name: D.L. Condition #: 15 (Demo/Told)		Non-Scientific Conceptions	Scientific Conceptions
Pretest Info & Scores			
HS & College Science Courses	6	Lack of forward motion (carried, tossed) >	Idea of 2 forces (launched)
True/False Test	5/10	Arced path ⌒	
Application	1/2	Simultaneity =	
Post Demo Info & Scores			
True/False Test	18/21	Lack of forward motion > (tossed)	Simultaneous external force (launched, carried) = ●
Application Test	2/2	Arced path (launched) ⌒	
Short Answer Test	8/8		
Mini-Lesson	6/10		
Attitude Questionnaire	Knowledge 3 Attitude 8 Importance 7.7 Usefulness +		
Video Lesson Info & Scores			
Knowledge	6/10		Simultaneous combination of 2 forces =
Teaching	8/10		
Student Rating	8/10		
Interview			External forces act like pressure ● (Treatment caused her to realize previous ideas were wrong.)
Delayed Posttest Info & Scores		Lack of forward motion > (tossed)	Simultaneous combination of 2 forces =
True/False	19/21		
Application	2/2		

⌒ Arced path
> Forward motion
= Simultaneity
● Inner force

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